CITE-AHU:
An Automated Commissioning Tool for CAV Air-Handling Units

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CITE-AHU Commissioning of the Installation and Technical Equipment -Air Handling Units

Outline

- Commissioning Process
- Development of CITE-AHU
  - ☐ Test automation
  - ☐ Expert rules
  - ☐ Interface
- Commissioning the ARIA Building
  - ☐ Design Review
  - ☐ Manual Cx Results
  - ☐ Automated Cx Results
- Savings Estimate/ Payback
- Conclusions

AHU Commissioning Process (from CTPL)

M
A
N
U
A
L

B
E
M
S

Step 1: Design Review-

check control logic, <u>sensor placement</u> and sensor accuracy.

not currently emphasized in protocols

Step 2: Operator Interview-

for existing buildings, ask building operator whether the air handling units are operating properly to the best of their knowledge.

iterative!

Step 3: Installation Review and Verification-

conduct a field inspection to determine installed characteristics of the equipment including condition and sensor availability

update documents

Step 4: Forced Response Testing and Analysis-

complete passive testing with BEMS, <u>before</u> active testing

manipulate the system under test by means of setpoint changes and sensor overrides. Document along with mode changes.

Evaluate data for compliance.

Automation of functional test scripts

1. Verify communications link
2. Run pre-coded test sequence from library

Value Displays as READ is completed

This is the line number to input to change reference value

Index	Date (dd/mm/yyyy)	Hour (hh)	Min(mm)	Mode	Adress (Desigo's Software	Action	Value	S
1	27/01/2004	09	15	READ	ARIA_DL_d002_PLT13_PAR3	24		C
2	27/01/2004	09	15	WRITE	ARIA_DL_d002_PLT13_PAR3	L1	+6	C
3	27/01/2004	09	15	READ	ARIA_DL_d002_PLT13_PAR1	20		C
4	27/01/2004	09	15	WRITE	ARIA_DL_d002_PLT13_PAR1	L3	+1	C
5	27/01/2004	09	45	READ	ARIA_DL_d002_PLT13_PAR1			C
6	27/01/2004	09	45	WRITE	ARIA_DL_d002_PLT13_PAR1	L5	+1	C
7	27/01/2004	10	15	READ	ARIA_DL_d002_PLT13_PAR1			C
8	27/01/2004	10	15	WRITE	ARIA_DL_d002_PLT13_PAR1	L7	+1	C
9	27/01/2004	10	45	READ	ARIA_DL_d002_PLT13_PAR3			C
10	27/01/2004	10	45	WRITE	ARIA_DL_d002_PLT13_PAR3	L9	-6	C
11	27/01/2004	10	45	WRITE	ARIA_DL_d002_PLT13_PAR1		20	C
12								
13								
14								
15								
16								
17								

EXECUTE SCENARIO 2.1
Projet: test3.sce   ON GOING   27/01/2004   9 : 18

open scenario   Save scenario   Execute scenario   Stop   Quit

Procedure for Cx Analysis

Détection de la centrale
Composition de la centrale

Type de CTA

- CAV
- VAV

Composition de la CTA

- ☐ Heat
- ☐ Cooling
- ☐ Humidify
- ☐ Recovery
- ☐ Mixing

1. Import test data
2. Specify data relationships
3. Specify system functionality
4. Analyze using modified APAR rules
5. Compare to archived tests for On-going Cx

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Files   Database   Options   Help

Week 28   Year 2003   GO   Normal filter   Fault list

Legend

☐ No Faults   ☐ 1 to 4 Fault(s)   ☐ More than 5 Faults

FORCED RESPONSE TEST

CTA	DATA	Total	TEST N°	1	2	3	4	5	6	7	8	9	10

Expert rules- AHU Performance Assessment Rules (House)

- Enhanced for constant air volume systems
- Considers additional equipment (heat recovery)

CITE-AHU

Files Database Options Help

Buildings/batiment/AHU/AHU3 : Data3

Week 23   Year 2000   GO   Normal filter   Fault list

Legend

No Faults   1 to 4 Fault(s)   More than 5 Faults   ADEME CSTB

Results Table- Week of 05/29/2000 to 06/04/2000   ON-GOING COMMISSIONING

AHU name	Data sheets	Fault	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
AHUs :									
AHU3	Data3	98	16	10	15	16	16	13	12
AHU1	Data1	57	5	6	3	16	16	1	10
AHU2	Data2	14	1	4	1	0	7	1	0
AHU4	Data4	14	0	0	1	0	11	2	0
AHU5	Data5	34	14	15	3	0	0	0	2
CSTB2	DataC2	0	0	0	0	0	0	0	0
CSTB 3	DataC3	0	0	0	0	0	0	0	0

Enable / Disable Rules   ok

CITE-AHU

AHU3

Modes

Heating

Faults

☑ FAULT : 1
☐ FAULT : 2
☑ FAULT : 3
☐ FAULT : 4
☐ FAULT : 29
☐ FAULT : 30

Rule 1

$$Tsa < Tma + \Delta Tsf - \varepsilon t$$

In heating mode, if the supply air is not greater than the mixed air plus the temperature rise across the supply fan then there is an inconsistency in the temperature measurements.

Provides greater transparency of rule logic (tool tips)

Start   FDD-AHU   ASHRAE2004.ppt   AHU_Scenario.ppt   Error - Microsoft...   3:52 PM

6

Commissioning the ARIA Building

Step 1 Design Review: AHU3
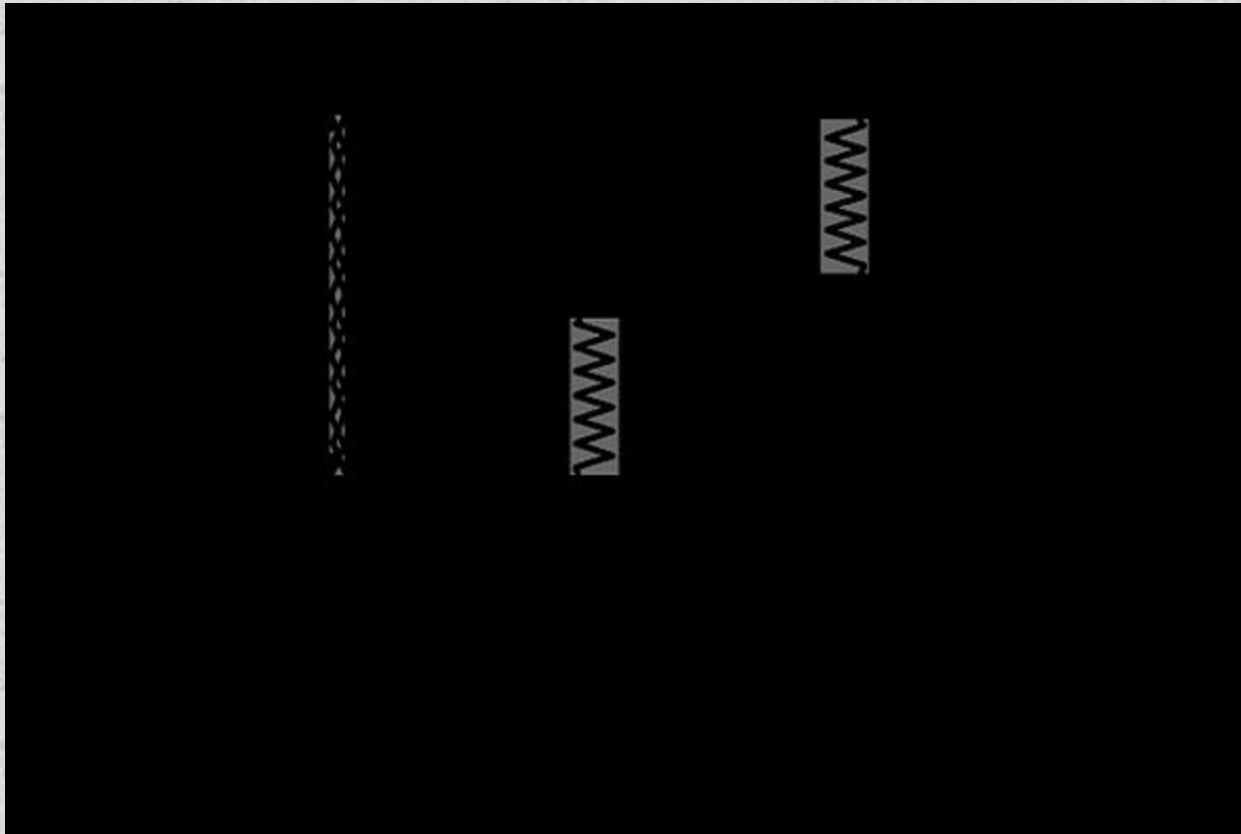
- **Serves Offices & Converted space**
- **100% outdoor air**
- **Modes:**
  - ☐ **Heating**
  - ☐ **Free cooling**

  w/ Heat recovery & Manual Bypass

# Step 2 Operator Interview: Mr. Laurent Auriau

■ Candid w/ good knowledge of (undocumented) system history.

UNIT	PROBLEM DESCRIPTION
AHU3	Zones partitioned for office spaces w/o changing ventilation configuration
General	Cannot change the controllers schedule, setpoints revert to a nightly shutoff at midnight and 05:00 startup
	⋮

Step 3 Installation Review and Verification

Outdoor Air Temp. Sensor
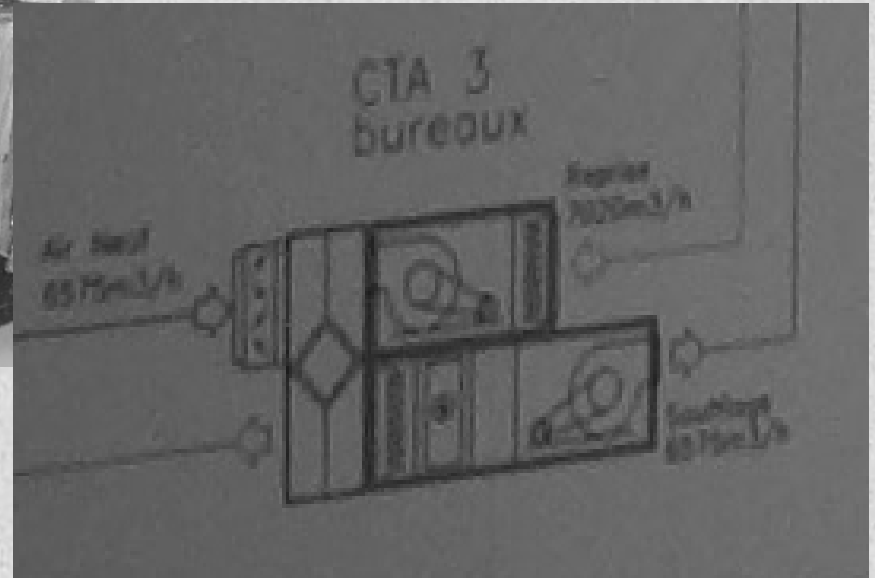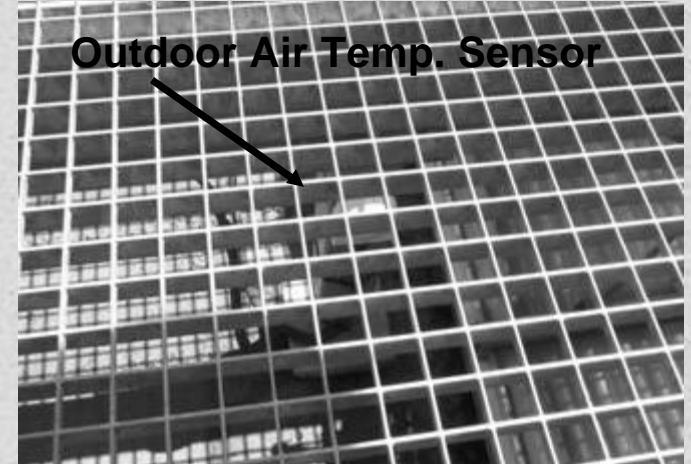
Step 4 Forced Response Testing and Analysis (passive w/ BEMS)

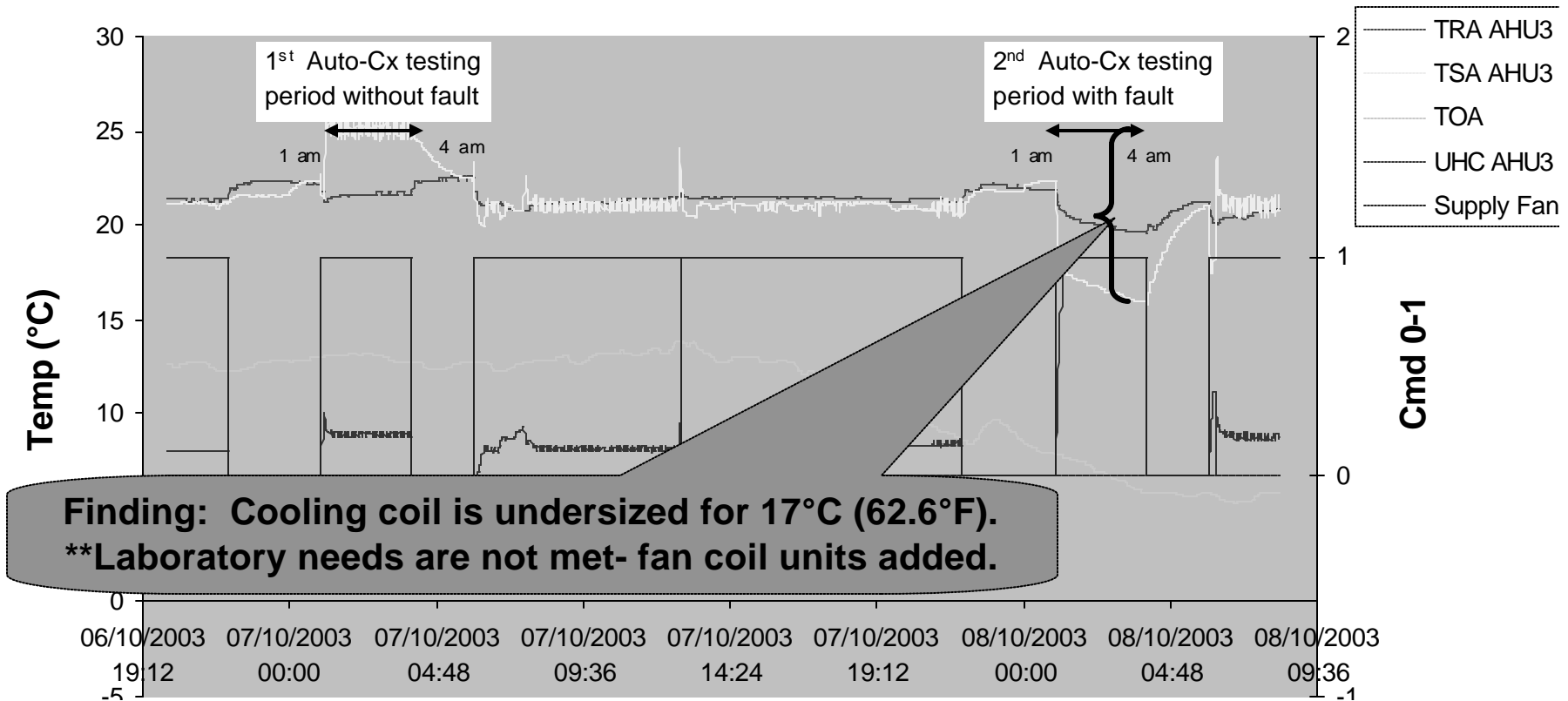| UNIT	PROBLEM DESCRIPTION & EFFECT
ALL	System schedule in override. (Controls installer left test program active)

Step 3 Forced Response Testing and Analysis (active w/ BEMS)

First Auto Cx tests were conducted on AHU3 over two nights
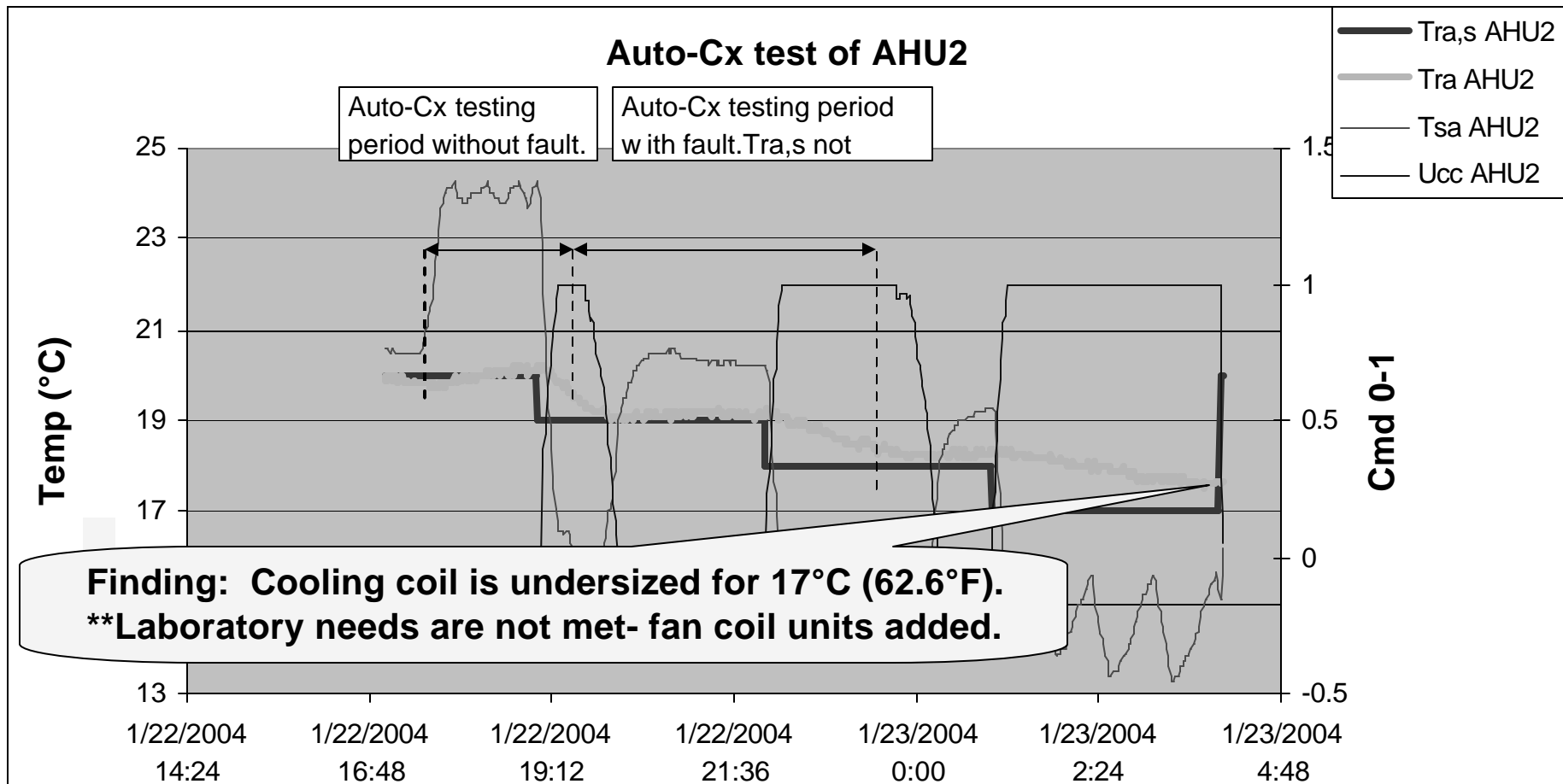
1st night- Fault free with
pumps in manual override

2nd night- Faulty condition BEMS
logic error causes pumps to cycle off

**Finding: Cooling coil is undersized for 17°C (62.6°F).
**Laboratory needs are not met- fan coil units added.**

Step 3 Forced Response Testing and Analysis (active w/ BEMS)

AHU2 Cooling coil capacity step test:

Return Temp. setpoint is changed from 20°C -> 19°C (3 hours) -> 18°C (3 hours) -> 17°C (3 hours)

Auto-Cx test of AHU2

Legend:
- Tra,s AHU2
- Tra AHU2
- Tsa AHU2
- Ucc AHU2

Auto-Cx testing period without fault.

Auto-Cx testing period with fault. Tra,s not

Finding: Cooling coil is undersized for 17°C (62.6°F). **Laboratory needs are not met- fan coil units added.

| Unit	Fault	Solution
AHU3	Operating with heat recovery in summer	Automate damper control based on outdoor and return air temperatures
AHU1, 2 and 3	Outdoor air temperature	Provide sensor shading
AHU1,2	Return air temperature sensor is located downstream of the outdoor air supply duct	Correct the location of the return air temperature sensor
AHU 3	Supply air temperature setpoint (21° C), results in nighttime heating in summer	Reduce supply air temperature setpoint in summer
Boilers	Boilers in manual override in summer	Apply summer schedule
Chiller	Condenser is 50% fouled	Clean condenser fins
AHU1,3	Exhaust duct from AHU1 is connected to the exhaust of AHU 3	Redesign exhaust system for AHU 1 and update design drawings
AHU3	Nighttime shutdown not in effect	Shutdown system 12 am - 5 am
AHU1, 2 and 3	Forced continual operation of AHUs due to a test program installed in 2000	Remove test program

**Green= Manual Cx   Blue= Bems Assisted Cx   **Orange= comfort   Yellow= energy 13

Unit	Fault	Solution
AHU2, Chiller	AHU2 is set for 24 hour operation which does not match the operation of the chilled water pumps, stopped 12am-7am	Synchronize equipment operation
AHU1	The cooling coil of AHU1 was added after the construction of the building and is connected directly to the chiller (without a separate pump) It is not possible to suspend delivery of cooling water to this AHU	Add a dedicated pump for cooling coil
Boilers	Boilers operate even when commanded off (pumps shut down, boilers still operate)	Force at least one boiler to stop
AHU3	AHU3 circulation pump cycles with the boiler. The heating coils are not supplied with hot water when the boilers cycle off.	Ensure that the circulation pump operates independent of the boiler.
Boilers	The open period of the boiler isolation valves (3 mn) is too long for the on/off period of the boilers (2mn)	Reduce the open period of the boiler isolation valves to 1mn
AHU2	Return air temperature sensor reading does not match overlay sensor, system sensor is faulty.	Replace faulty temp sensor

Gas Savings Estimate

Correct the boiler control logic

- Boiler plant ran 24/7 to avoid occupant discomfort.
- The control logic error was corrected January 5, 2004.
  - □ improved comfort for occupants
  - □ decreased gas consumption
  - □ increased protection of the boiler plant equipment.

Weekly Gas Consumption vs Mean Outdoor Temp (C)
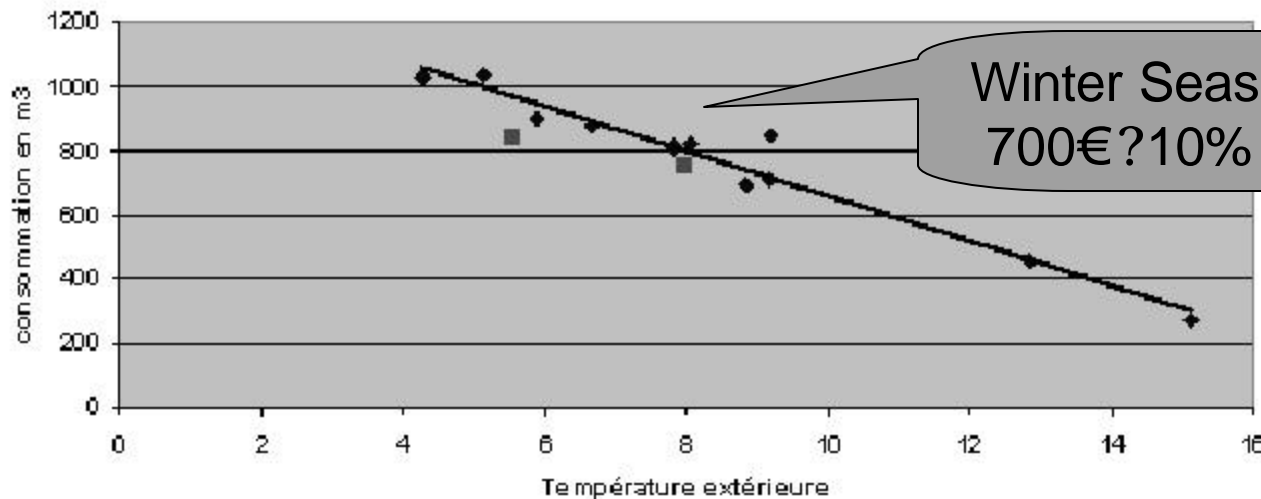
Winter Season Estimate:
700€?10% Gas Energy Savings

Electrical Energy Savings Estimate

Correct scheduling errors for AHUs and pumps

Annual estimate:
4141€ ? 47% Electrical Energy Savings

Equipment	Power (kW)	Energy use before Cx (kWh)	Energy use after Cx (kWh)	Energy savings (kWh)	Cost savings €
Fan AHU 2	2.2	19219	8580	10639	798
Fan AHU 3	8	69888	33280	36608	2746
Pump AHU & FCU (HW)	0.4	3494	1664	1830	137
Pumps Zone 1,2,3	0.067	585	279	307	23 x 3
Pump Zone 4 (HW)	0.047	410	196	215	16
Pump Zone 5	0.169	1476	703	773	58
Pump AHU & FCU (CW)	0.825	7207	3432	3775	283
Pump Zone 4 (CW)	0.1	873	416	457	34

Conclusions

- Some adaptation required for new systems
- CITE_AHU detected 3 faults in 4 automated tests
    - Scheduling errors (€)
    - Cooling Coil & Heating coil Undercapacity
    - Boilers sequencing
- Development of automated tools must be used in conjunction with good protocol for system design reviews
    - ☐ Limitations to automated testing (i.e., detecting sensor placement errors)
- Quantitative energy benefits
    - ☐ Excludes service requests
    - ☐ Equipment life
    - ☐ Heat recovery

Total gain	5000 €
Project cost	15000 €
Pay back	3 years

- Non-quantitative benefits also achieved- comfort, operator knowledge, maintenance, documentation

Future development

- Define specific test scenarios (with user-changeable parameters)
- Integrate test scenarios into CITE_AHU interface
- Automate documentation of test results
  - Incorporate required manual test and documentation archive
- Test VAV systems, Expand for other configurations

- Investigate Manufacturer interest to provide integrated package.

Questions?